TUNNEL WATER ISSUES 4/27/2011

INTRODUCTION

There are three major sources of inflow and infiltration into the tunnel system.

1.) Storm water that is carried by vehicles and the airstream they create.
2.) Storm water that bypasses drainage infrastructure at the tunnel portals.
3.) Infiltration of groundwater via cracks, conduit penetrations, and joints.

Tunnel wash water and water from fire fighting is of minor or negligible contribution. An overall estimate of the proportion of quantities of water discharged by source is: 10%, 30% and 60%, respectively.

Infiltration of water into the CAT tunnels has occurred since the first CAT tunnels were constructed and opened in 1995. Due to the recognition of the damaging effects of the continual moisture on electrical and structural tunnel components numerous commissions, surveys and studies have been performed since 1997 most notably: Leak Task force 2000- 2004, Gerwick Report 2004, FHWA Leak assessment team report 2005, STS consultants statistical analyses 2006, WJE Stem to Stern Report 2007, Mass Turnpike Authority Tunnel Water Management Program Draft 2008. The commissions were convened and studies were carried out for various purposes including: to evaluate effectiveness of designs, to attempt to quantify the issue in terms of infiltration type and location, to assign responsibility to contractors and designers, to provide completion projections, to provide general guidance, to perform statistical analyses to help focus efforts to alleviate the problem and to describe the issue and how it is being managed.

Although the leak issue was actively being addressed in the past, a large breach in slurry wall of the O'Neill Tunnel in 2004 caused a partial closure of the tunnel during the pm rush hour and consequently elevated the issue to a level of national attention since that time. Additional scrutiny of the tunnel water issue is now being fueled by regulations pertaining to discharge type and amount with the MWRA and BWSC and the environmental regulatory agencies DEP and EPA. However, management of the tunnel water focus remains on maintaining tunnel safety and minimizing damaging effects of moisture on structural and electrical components.

WATER DISCHARGE ISSUE

The tunnels are designed to collect and discharge all water entering the tunnels including groundwater, wash water, firefighting water and some storm water. Collected water is discharged to the BWSC sanitary sewer system which flows to the MWRA conveyance system and ultimately to the sewage treatment facility on Deer Island. There are 16 low Point Pump Stations in the MHS tunnel system, at

10 locations discharge to MWRA occurs. Five of the pump stations pump into adjacent pump stations and 1 pumps into surface water as it is the oldest tunnel.

A separate storm water collection system captures water prior to the tunnel portals and discharges to the Charles River and Boston Harbor. There are 27 storm water pump stations.

The regulatory framework is such that the CAT tunnel water is subject to the regulations of the BWSC and MWRA. There are three separate discharge permits for the tunnels, one each for the TWT, I-90 Connector and O'Neill Tunnel. The regulatory issue begins with the initial discharge permits to allow tunnel construction describing only provisions for tunnel wash water and water from firefighting flows and a negligible amount of inflow and infiltration. Discharges to MWRA via BWSC infrastructure exceed permitted types of flow as they include infiltration and inflow. Additionally, permitted volumes are exceeded as well.

Modified permits issued by MWRA include monthly reporting of our water discharge volumes and efforts to eliminate infiltration to MWRA, DEP and EPA. Efforts to minimize infiltration have been undertaken by continuation of leak sealing efforts at an average cost of $12M per year. Additionally, there is a plan to install diversion valves at all CAT tunnel pump stations that discharge to MWRA. The diversion valves are intended to convey the tunnel water to the nearest storm water discharge system outfall which drains into the Charles River and Boston Harbor instead of pumping it to the MWRA Sewage Treatment facility on Deer Island. The diversion or bypass valves would be redirected back to MWRA during tunnel washing and subsequent flushing periods. The system has been designed using CAT Trust Fund resources (CRC12), however, construction of this system discharging directly to surface water has not yet been permitted due to regulations of DEP and EPA and concerns of water quality and elevated levels of dissolved metals.

An additional measure of replacing 51 tunnel portal trench drains to intercept storm water inflows coming from outside the tunnel in a more efficient manner has been designed and advertised. (CRC 5).

ANALYSIS OF PUMPING VOLUMES

To comply with tunnel water discharge permit conditions the amounts of tunnel water discharge have been continuously monitored based on correlations with pump run times since 2007. Currently the combined total volume of discharge is approximately 17 million gallons per year. The permitted total is significantly less.

The discharge volumes have also been useful for the management and effectiveness of leak sealing efforts and identifying trends to understanding the tunnel leak and inflow behavior. Based on data collected since 2007, there is a

cyclical correlation of flows to both temperature and rainfall: the lower the temperature the higher the volume of discharge. Additionally, the in time of greater precipitation there is a higher the volume of discharge. The correlations affect the three tunnels permitted to discharge to MWRA somewhat differently. For instance precipitation has a more significant effect on water volumes in I-93 while temperature has a more pronounced effect in the I-90 connector. This observation is confirmed by the presence of more ramps and missing portal trench drains in I-93 and by the more monolithic structure of the I-90 connector. The I-90 connector has areas of known construction joints that open up during cold weather at discrete locations such as at a location known as the 'superplug' due to larger than expected temperature induced contractions.

Additionally, the discharge data has shown the continual leak sealing efforts along I-93 since 2007 have been effective to reduce leaks as a downward trend of leak related outflow exists. In contrast the data confirms field observations that for I-90 repairs to the discrete but larger construction joints such as at the 'superplug' have not been effective and more extensive repairs that are in the planning stages are necessary to maintain long term tunnel integrity. These repairs involve deep excavations around the outsides of the tunnel box.(CRC4, 4A)

INFILTRATION, TUNNEL LEAKS

As inflow into the tunnels generally only affects discharge volumes and presents a permit issue it is generally not detrimental to the tunnel structure or safety as it is quickly captured by the tunnel drainage system. However, infiltration of groundwater or tunnel leaks are a more vexing problem as they are widespread throughout the tunnel and are the cause of safety concerns and has a damaging effect on the tunnel structure and equipment. Additionally, identification of the location of the origin of the leaks is a difficult an time consuming task as often a dripping of water needs to be traced back to it's origin through the various tunnel components or chambers. This task is complicated by the lack of instant availability of lane closures as leaks change in character and flow rate due to temperature fluctuations.

Leaks are the cause of numerous roadway icing conditions and accelerate corrosion by requiring deicing chemicals to be applied inside the tunnels. Deicing salts are noted as causing premature corrosion of the light fixtures. In addition, the application of salt in the tunnels has caused exceedances in airborne particulate matter and concerns by DEP have been noted.

Leaks have impacted the ability of the ventilation system to operate by restricting airflow due to the filling up of supply air ducts (SAD) and well as exhaust manifolds (VB3). Although there is an ad hoc system of submersible pumps in the Supply air ducts to clear this water, however, during the winter water accumulates and freezes before reaching the pumps creating blockages in the

SAD's. A CAT Trust Fund project to install a more permanent and freeze resistant SAD pumping system is in the planning stages.

Other direct safety effects of the leaks include build up of mold such as in VB4 and certain utility rooms.

Leaks greatly contribute to the moist corrosive tunnel environment and there is widespread corrosion of electrical components and conduit. There is initiation of corrosion of structural steel, soldier piles and girders supporting the tunnel roof along I-93. Freeze thaw damage exists on concrete surfaces where leaking cracks exists. Additionally, many electrical conduits are filled with water while the conductors inside them are not rated for submersed conditions.

There is current an effort being completed to replace approximately $10M fireproofing caused by water saturation and failure onto the roadway below. The fireproofing is used to protect structural steel components of the tunnel exposed to the travelled roadway and utility raceways that convey cables life safety equipment such as lighting, video, fire alarm etc.

There are several published norms for acceptable quantities of infiltration for tunnels. Noteably, a FHWA criterion is 1 gallon per minute per 1000 feet of tunnel. Some reports have taken this criterion and calculated that the CAT tunnels are within this limit, however, this is a useless comparison as it does not quantify damage caused by the water and should only be used for discharge calculations.

LEAK TYPES

There are a tremendous variety of leaks types and examples within the CAT of them. They can be categorized in numerous ways and are listed below:

- Embedded grout tubes (fuko hoses)
- Conduit systems including pullboxes and manholes
- Conduit penetrations
  - NESI
- Abandoned construction conduits and penetrations
  - The 'glacier' at VB6
  - Ramp RT/i93 exhaust Duct
- Roof to wall interface waterproofing membrane gap
- Soldier Pile Tremie Concrete Wall issues (Slurry Wall type)
  - embedded QA pipes
  - soldier pile separations
  - wall cracks
  - wall soil inclusions (2004 EO45 panel)
  - End stop remnants
  - top of wall infiltration

Construction Joints

- Super Plug (CRC4, 4A,)
- C01A3/C04A2 interface
- Dewey Square connection
- Red Line Area
- Boat to Tunnel connections

Expansion Joints

- I-90 ITT, TWT VB6
- Ramp interface joint (CRC trench grates)

Base Slab cracks
Supply Air Ducts
Buildup/overflow in Inert chambers - bathtub effects CP20 Void space (CRC 6)
Utility rooms

In hindsight, there are different causes of the leaks that are summarized as follows:

1.) Inadequate details of waterproofing membranes and improper installation.

2.) Water travels in embedded conduits, membrane backer cushions and regrout tubes and conveys water over long distances from the point of water entry occurs. These are exceeding difficult to trace.

3.) Inadequate installation or design details of Soldier Pile Tremie Concrete (SPTC).

4.) The failure of design to consider a higher temperature swing for the calculation of expansion and contraction of tunnel structure. The CAT Design assumes a 50 degree temperature swing. Due to the continual ventilation of the tunnels and subsequent heating and cooling to ambient air temperatures a 100 degree temperature swing should have been used.

INSPECTION

All tunnels are inspected and tested in accordance with Policy Directive issued by MTA in 2007 and adopted by MassDOT in 2010. At present all tunnels are divided into individual sections referred to as BIN's and consistent with the Bridge inventory protocols currently in use for Bridge inspection. There are 150 tunnel sections or BIN's. The policy requires semiannually that the life safety systems preventive maintenance tasks completed are reported and that all ventilation zones are tested for emergency activation. Annually all overhead elements are required to be inspected and triennially the remainder of the tunnel and vent buildings are inspected. The entire effort currently costs approximately $3.2 M per year.

For leak related information, each routine tunnel inspection form has a "Wetness" section in which condition codes are assigned to the tunnel components within the BIN (structural, roadway, Ceiling, overhead, supply air duct, exhaust air duct, cross passage, egress, utility room). The condition codes are based on an established "wetness rating guide". In addition to the coding more specific information is noted in the "remarks" section of the report.

The inspection data along with observations reported by maintenance and construction personnel in performing tunnel work are used to direct work crews for leaks sealing efforts.

LEAK SEALING EFFORTS

The approach to leaks sealing efforts is not to go after every leak noted but instead to prioritize in the following manner:

1.) roadway wetness (avoid ice)
2.) Corrosion concerns - Structural, electrical
3.) Volume reductions or continuous leaks

Currently leak sealing efforts are being conducted by JF White under CRC1 which is an approximately $36M construction contract funded by the Cat Trust Fund. The contact is forecasting to deplete funds in October and a request for additional funds of $13M to continue leak sealing efforts. Approximately 5 to 8 crews work in I-93 tunnels nightly. Generally, winter and spring is when the greatest number of crews are working as temperature induced contractions have caused maximum leakage during these time period.

Due to the complexity of the tunnel structures and leaks types encountered the current program relies on various means of reducing infiltration ranging from concrete repairs, application of steel plates, installation of waterstops, gaskets, mechanical plugs, redirection of inflows, and application bentonite grouts, portland cement based grouts, coatings and chemical grouts. Chemical grouts vary from expansive polyurethane foams, asphaltic based void fillers and acrylate based grouts depending on site specific conditions. The most commonly used product is an acrylate resin when mixed with sodium persulfate in water creates a very low viscosity liquid which can be pumped into fine cracks and will set up in numerous wide ranges of conditions depending on the portions of persulfate and hardener added.

The contractors are paid for three types of leak repair by the crew hour pay unit: type I, type II, type III repairs each type having respectively more difficult access requirements to the source of the leak.

Additional past and proposed infiltration and inflow reduction related contracts are listed below: All are or are contemplated to be trust fund eligible.

CRC1-$36M, complete 9/1/11
CRC 1A (C19BA- 8$M) completed
CRC1B- $13M requested – continue CRC1 until replacement contract is awarded
CRC1C -$45M requested I-93 continuation of CRC1
CRC 4 - $6M - I-90 plug investigations, ramp joints
CRC4A -?? ($10M) – Superplug sealing
CRC 5 - $10M approved – Portal Trench drains replacement
CRC 6 - $5M (CP#20 void space)- under development
CRC 12 - $3M approved - permit issues